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Original communication

Sex determination of human crania using Mastoid triangle and Opisthion–Bimastoid triangle

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ABSTRACT

In the present study an attempt has been made to establish standards for sex determination from the various direct and indirect measurements of the cranium. A total of 100 cranium (50 of either sex) were measured for nine direct measurements pertaining to Mastoid triangle and Opisthion–Bimastoid triangle. These measurements were used further to calculate four indirect measurements pertaining to the calculation of Opisthion–Bimastoid triangle area and angles.

Analysis of data reveals that the male crania exhibit greater values for all the measurements except the angle right Mastoidale–Opisthion–left Mastoidale. The sex difference has been observed to be statistically significant for all the measurements except for the angles of the Opisthion–Bimastoid triangle. Sectioning point was calculated for the diagnosis of sex based on the mean values of these measurements; the accuracy of sex determination varied from measurement to measurement. The highest value for determining sex was obtained for Asterion–Mastoidale length of right side i.e. 80%, followed by Bi-mastoid breadth i.e. 75%. This suggests that these measurements could be used with relatively high degree of accuracy in determining sex of the unknown crania.

1. Introduction

Identification of human skeletal remains is of major importance in medico-legal situations such as criminal cases, mass disasters and human rights abuse investigations.[15] One of the principal biological indicators of identity is the sex of an individual. This is relatively uncomplicated to achieve when the remains are complete, but fragmented or dispersed remains result in an incomplete assessment, which may lead in inconclusive identity, including sex evaluation. Almost all bones of the human skeleton show some degree of sexual dimorphism including teeth. The sex is best assessed from the pelvis, while the skull is considered as second best area for sex determination.[1] Success in sex determination depends upon the completeness of the skeleton. Often fragmentary remains are available, instead of, complete skeletons for forensic identification. Henceforth, individual parts of the skull like mastoid process, hard palate, basal region, occipital condyle, foramen magnum or some other parts have been analysed by few researchers for sex determination.[3,4,7,14,20–22]

It is therefore essential that every part of the human skeleton be assessed on its own merit to determine its value for identification purposes as the investigator has no influence over which elements may be presented for examination.

Ability in cranial sexing claimed by different authorities shows considerable variation. Borovanski [2] examined 247 skulls of known sex and opined that from observational criteria only 10% are impossible to sex. Keen[8] did valuable survey and by use of a combination of four measurements and three observations, he was able to sex correctly about 85% of his material. Paiva and Segre[16] evaluated the significance for sex determination using the measurement of area formed by the 3 craniometric points pertaining to the mastoid process: the Porion, Asterion, and Mastoidale points and on the basis of the values obtained, male and female crania can be discriminated with 95% confidence. Kranioti et al.[11] examined 90 males and 88 females of Balkan and Greece area by taking sixteen dimensions from the craniofacial skeleton. The results indicated that with the help of single dimension accuracy of 82% is achieved, while by using stepwise method (involving five dimensions) accuracy is enhanced to 88.2%. Kimmerle et al.[10] examined the effect of size and sex on craniofacial shape among American population for sex determination. Three dimensional coordinates of sixteen standard craniofacial landmarks were collected and the sexing accuracy varies from 73.3% to 93.10% with different variables. Stevenson et al.[19] worked on 304 skulls of known sex of English, African American and European American origin and met

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the criteria of 75% of correct sex determination. Green and Curnoe[6] evaluated 89 males and 55 females from South-East Asian crania and results shows the significant size dimorphism and the overall expected accuracies were highest in discriminant analysis using shape and centroid size (86.81%). Manoel et al.[12] worked on the morphometric analysis of the foramen magnum in 215 human skulls of Brazil and were able to determine the morphological differences between sexes. He further suggested that morphological differences along with other anthropological techniques could be used for gender determination of unknown individuals.

The present study aims to evaluate the sexual dimorphism in Mastoid triangle measurements and the area, angles and dimensions of the Opisthion–Bimastoid triangle, as it is more protected region and resistant to damage, due to its anatomical position at the base of the skull.

2. Material and methods

Present study is based on the measurements obtained on 100 completely dried and fully ossified human crania (50 of either sex). It was also ascertained that the crania considered for the present study were free of any kind of damage. Juvenile skulls were also excluded from the study. The initial examination of all the crania was done following the non-metric observations to categorize them into male and female category.[17] A total of nine direct measurements pertaining to Mastoid triangle and Opisthion–Bimastoid triangle (Mastoid–Opisthion–Mastoid) were taken on each cranium in accordance with the standard measurement techniques recommended by Martin and Saller, and Singh and Bhasin.[13,18]

1) Asterion–Mastoidale length (left)
2) Asterion–Porion length (left)
3) Porion–Mastoidale length (left)
4) Asterion–Mastoidale length (right)
5) Asterion–Porion length (right)
6) Porion–Mastoidale length (right)
7) Bimastoid breadth (left Mastoidale to right mastoidale)
8) Mastoidale–Opisthion length (left)
9) Mastoidale–Opisthion length (right)

These measurements were used further to calculate four indirect measurements pertaining to calculation of Opisthion–Bimastoid triangle.

10) Angle of Opisthion–left Mastoidale–right Mastoidale (<o–lm–rm)
11) Angle of left Mastoidale–right Mastoidale–Opisthion (<lm–rm–o)
12) Angle of right Mastoidale–Opisthion–left Mastoidale (<rm–o–lm)
13) Area of Opisthion–Bimastoid triangle

Asterion–Mastoidale length (ast–ms) – It is the straight distance between Asterion and Mastoidale. (Right and left both)

Asterion–Porion length (ast–po) – It is the straight distance between Asterion and Mastoidale. (Right and left both)

Porion–Mastoidale length (po–ms) – It is the straight distance between Porion and Mastoidale. (Right and left both)

Bimastoid breadth (ms–ms) – It measures the straight distance between the two Mastoidale.

Mastoidale–Opisthion length (ms–o) – It is the straight distance between Mastoidale and Opisthion. (Right and left both)

Angle of Opisthion–left Mastoidale–right Mastoidale (<o–lm–rm) – Angle formed by the Opisthion–left Mastoidale–right Mastoidale.

Angle of left Mastoidale–right Mastoidale–Opisthion (<lm–rm–o) – Angle formed by the left Mastoidale–right Mastoidale–Opisthion.

Angle of right Mastoidale–Opisthion–left Mastoidale (<rm–o–lm) – Angle formed by the right Mastoidale–Opisthion–left Mastoidale.

2.1. Landmarks

Porion (po) – Superior point of the external auditory meatus.

Mastoidale (ms) – Most inferior point of the mastoid process.

Asterion (ast) – The meeting point of the lambdoid, occipito-mastoid and parieto-mastoid sutures.

Opisthion (o) – It lies on the posterior margin of the foramen magnum which is intersected by the mid-sagittal plane.

All these measurements have been shown in Figs. 1–3.

After taking the measurements, cranium was numbered to avoid repetition. Bean bag was used for placing the cranium at the time of taking measurements.

2.2. Method of formulating Opisthion–Bimastoid triangle and measuring the angles and area

To measure the angles, triangle was drawn on the paper with the help of the three direct measurements (Bimastoid breadth, left Mastoidale–Opisthion length and right Mastoidale–Opisthion length) taken on the cranium. Bimastoid breadth was taken as the base of the triangle. From the left Mastoidale (lm) using the compass the distance up to Opisthion (o) was marked as an arc. Finally from the right Mastoidale (rm) the distance up to Opisthion (o) was taken and marked to cut the earlier arc to get the point Opisthion (o). Subsequently all the three points were joined to form the triangle. After drawing the triangle, <o–lm–rm, <lm–o–rm and lm–rm–o were measured with the help of protractor.

Area was calculated by using Heron's formula.[9] With sides a, b and c;

$$A = \sqrt{(s(s-a)(s-b)(s-c))}$$

and,

$$s = (a+b+c)/2$$

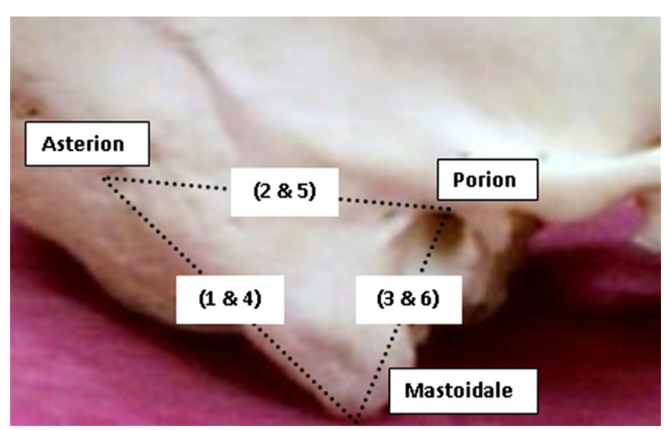

Fig. 1. Lateral view of the cranium depicting the Mastoid triangle as defined by the landmarks mastoidale (ms), Asterion (ast) and opisthion (o) and showing the measurements 1–6 used for the study (as per the above list).

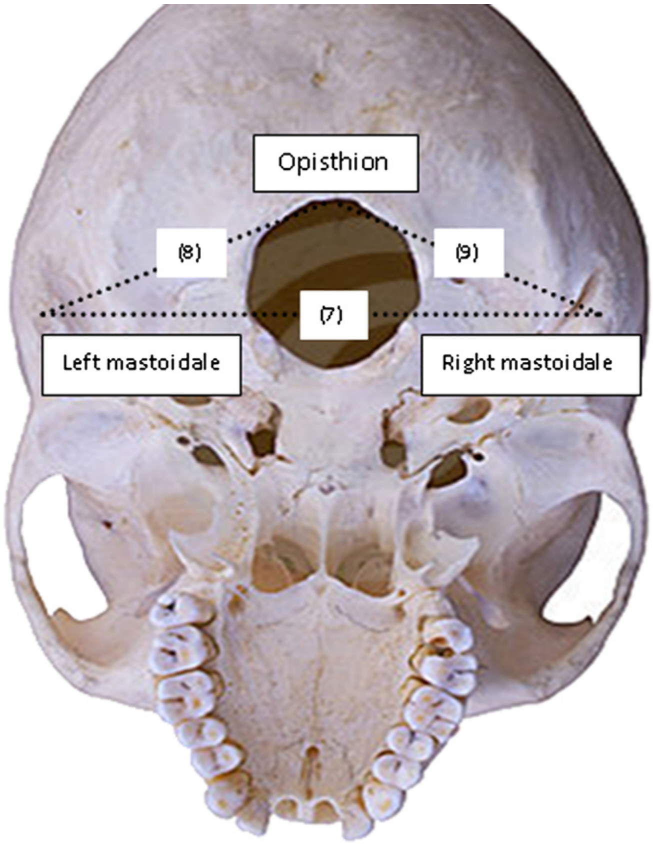

Fig. 2. Basal view of the cranium depicting the Opisthion–Bimastoid triangle as defined by the landmarks left and right mastoidale (ms) and opisthion (o) and showing the measurements 7–9 used for the study (as per the above list).

The data have been treated statistically using the standard programme of SPSS, to obtain mean, standard error of mean, standard deviation, test of significance. Besides these, sectioning point was also calculated for differentiating male and female cranium.[5]

Sectioning point $=$ mean of male $+$ mean of female$/2$

3. Results and discussion

Data have been subjected to statistical treatment for obtaining mean, standard deviation, standard error and t values for comparison of male and female crania.

Tables 1 and 2 present the mean values, standard error of mean and standard deviation for all the thirteen measurements (direct and indirect) of male and female cranium.

It is observed from the table that all the linear dimensions, area and the calculated angles were higher in males than the females

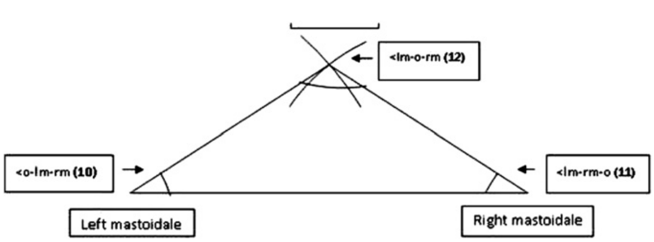

Fig. 3. Shows the Opisthion–Bimastoid triangle and how angles are measured by drawing it on paper and showing the measurements 10–12 used for the study (as per the above list).

Table 1
Measures of mean, standard error of mean and standard deviation for different measurements of male cranium.

Measurements	Mean	S.E. of mean (±)	S.D. (±)
Asterion–Mastoidale length (left)	4.929	0.112	0.805
Asterion–Porion length (left)	4.607	0.100	0.719
Porion–Mastoidale length (left)	3.105	0.071	0.510
Asterion–Mastoidale length (right)	4.952	0.113	0.809
Asterion–Porion length (right)	4.590	0.100	0.717
Porion–Mastoidale length (right)	3.135	0.075	0.536
Bi-Mastoid breadth/left Mastoidale–right Mastoidale	10.002	0.215	1.536
Left Mastoidale–Opisthion length	5.549	0.124	0.885
Right Mastoidale–Opisthion length	5.611	0.119	0.854
Angle of Opisthion–left Mastoidale–right Mastoidale	25.529	0.721	5.155
Angle of left Mastoidale–right Mastoidale–Opisthion	25.156	0.741	5.292
Angle of right Mastoidale–Opisthion–left Mastoidale	125.784	2.720	19.427
Area of Opisthion–Bimastoid triangle	12.687	0.399	2.853

Area was in cm^2, angles were in degrees, and other measurements were in centimetres.

except for the angle of right Mastoidale–Opisthion–left Mastoidale.

On subjecting the data to test of significance (t-test) to evaluate the sex difference, it is revealed that except for the angles of the Opisthion–Bimastoid triangle, all the measurements exhibit significant sex differences (Table 3).

Asterion–Mastoidale length of left side, Porion–Mastoidale length of left and right side, Asterion–Porion length of right side and area of Opisthion–Bimastoid triangle exhibit highly significant sex difference (at 0.01% level).

Table 4 represents the sectioning point for all the thirteen measurements, and on the basis of these values an attempt has been made to discriminate male and female more accurately.

4. Test and applications

To test the reliability of sectioning point, it was applied on a test series of cranium with known sex. The test sample consisted of twenty cranium of known sex by the help of morphological features[17] and the percentage of correctly identified sex varied from measurement to measurement. There are three categories, one that

Table 2
Mean, standard error of mean and standard deviation for different measurements of female cranium.

Measurements	Mean	S.E. of mean (±)	S.D. (±)
Asterion–Mastoidale length (left)	4.478	0.101	0.724
Asterion–Porion length (left)	4.309	0.092	0.659
Porion–Mastoidale length (left)	2.796	0.068	0.491
Asterion–Mastoidale length (right)	4.543	0.102	0.734
Asterion–Porion length (right)	4.200	0.088	0.633
Porion–Mastoidale length (right)	2.819	0.070	0.506
Bi-Mastoid breadth/left Mastoidale–right Mastoidale	9.325	0.194	1.388
Left Mastoidale–Opisthion length	5.135	0.107	0.769
Right Mastoidale–Opisthion length	5.211	0.109	0.780
Angle of Opisthion–left Mastoidale–right Mastoidale	25.333	0.723	5.167
Angle of left Mastoidale–right Mastoidale–Opisthion	24.882	0.730	5.217
Angle of right Mastoidale–Opisthion–left Mastoidale	126.254	2.732	19.511
Area of Opisthion–Bimastoid triangle	10.532	0.314	2.245

Area was in cm^2, angles were in degrees, and other parameters were in centimetres.

Table 3
Sex differences in different cranial measurements.

Measurements	*t*-values
Asterion–Mastoidale length (left)	3.047**
Asterion–Porion length (left)	2.223*
Porion–Mastoidale length (left)	3.295**
Asterion–Mastoidale length (right)	2.768**
Asterion–Porion length (right)	3.001**
Porion–Mastoidale length (right)	3.358**
Bi-Mastoid breadth/left Mastoidale–right Mastoidale	2.348*
Left Mastoidale–Opisthion length	2.567*
Right Mastoidale–Opisthion length	2.531*
Angle of Opisthion–left Mastoidale–right Mastoidale	0.192
Angle of left Mastoidale–right Mastoidale–Opisthion	0.264
Angle of right Mastoidale–Opisthion–left Mastoidale	0.122
Area of Opisthion–Bimastoid triangle	4.259**

*Significant at 0.05% level.
**Significant at 0.01% level.

is correctly identified, second is of doubtful origin and the third one is of incorrectly identified.

When the mean value of a particular measurement is greater than the sectioning point of that measurement then the specimen is of male origin and when the value is lower than the sectioning point, the specimen is identified as female and in case of equal values the specimen is of doubtful position; it can be either male or female. Table 5 summarizes the results and shows the percentage of correctly identified sex, doubtful and incorrectly identified sex of the cranium.

It may concluded from the table that the 80% of the crania were correctly identified by Asterion–Mastoidale length and Porion–Mastoidale length of right side, followed by Bi-Mastoid breadth i.e. 75% whereas in case of Porion–Mastoidale length (left), left Mastoidale–Opisthion length, right Mastoidale–Opisthion length and the area of the Opisthion–Bimastoid triangle, the result is 70%. Beside that 55% of crania were correctly identified by angle of right Mastoidale–Opisthion–left Mastoidale and 50% cranium were correctly identified by angle of Opisthion–left Mastoidale–right Mastoidale and angle of left Mastoidale–right Mastoidale–Opisthion.

It is observed that the 50% of the cranium were incorrectly identified by angle of Opisthion–left Mastoidale–right Mastoidale whereas 45% of the crania were incorrectly identified by Asterion–Porion length of left side, which is followed by angle of left Mastoidale–right Mastoidale–Opisthion and angle of right Mastoidale–Opisthion–left Mastoidale i.e. 40%. Crania were minimum incorrectly identified by Asterion–Mastoidale length of right side i.e., 15%.

Most doubtful cases were found in Asterion–Mastoidale length of left side i.e. 20%. Asterion–Porion (left), Porion–Mastoidale (left), right Mastoidale–Opisthion and angle of left Mastoidale–right Mastoidale–Opisthion had 10% incorrectly identified cranium and no doubtful cases were found in Asterion–Porion length (right) and Porion–Mastoidale length and the area of the Opisthion–Bimastoid triangle.

Table 4
Sectioning point of different measurements for discriminating male and female crania.

Measurements	Sectioning point
Asterion–Mastoidale length (left)	4.703
Asterion–Porion length (left)	4.458
Porion–Mastoidale length (left)	2.951
Asterion–Mastoidale length (right)	4.748
Asterion–Porion length (right)	4.395
Porion–Mastoidale length (right)	2.977
Bi-Mastoid breadth/left Mastoidale–right Mastoidale	9.663
Left Mastoidale–Opisthion length	5.342
Right Mastoidale–Opisthion length	5.411
Angle of Opisthion–left Mastoidale–right Mastoidale	25.431
Angle of left Mastoidale–right Mastoidale–Opisthion	25.019
Angle of right Mastoidale–Opisthion–left Mastoidale	126.019
Area of Opisthion–Bimastoid triangle	11.609

Table 5
Percentage of correctly identified, doubtful and incorrectly identified sex of the crania.

Measurements	Correctly identified	Doubtful	Incorrectly identified
Asterion–Mastoidale length (left)	60%	20%	20%
Asterion–Porion length (left)	45%	10%	45%
Porion–Mastoidale length (left)	70%	10%	20%
Asterion–Mastoidale length (right)	80%	5%	15%
Asterion–Porion length (right)	65%	0%	35%
Porion–Mastoidale length (right)	80%	0%	20%
Bi-Mastoid breadth/left Mastoidale–right Mastoidale	75%	5%	20%
Left Mastoidale–Opisthion length	70%	5%	25%
Right Mastoidale–Opisthion length	70%	10%	20%
Angle of Opisthion–left Mastoidale–right Mastoidale	50%	0%	50%
Angle of left Mastoidale–right Mastoidale–Opisthion	50%	10%	40%
Angle of right Mastoidale–Opisthion–left Mastoidale	55%	5%	40%
Area of Opisthion–Bimastoid triangle	70%	0%	30%

5. Conclusion

The present study revealed the following facts:

- Male cranium exhibits greater values for all the measurements than female cranium except for the angle right Mastoidale–Opisthion–Left Mastoidale.
- Sex differences were found to be significant for all the measurements except for the three angles of the Opisthion–Bimastoid triangle.
- Sectioning point was calculated for all the parameters to differentiate male and female cranium.
- 80% of the crania were correctly identified by Asterion–Mastoid length of the right side, followed by bimastoid breadth i.e. 75%.
- Porion–Mastoidale length (left), left Mastoidale–Opisthion length, right Mastoidale–Opisthion length and the area of the Opisthion–Bimastoid triangle correctly differentiates up to 70% of the cranium.
- 50% of the cranium were incorrectly identified by <lm whereas 45% of the crania were incorrectly identified by Asterion–Porion length of left side.
- 15% Crania were incorrectly identified by Asterion–Mastoidale length of right side.
- Most doubtful cases were found in Asterion–Mastoidale length of left side i.e. 20%.
- Results reveal that the percentage of the correctly identified cranium varies from measurement to measurement and the result varies from 80% to 40%.
- The three angles identify the sex between 50 and 55% only therefore these cannot be considered as reliable indicator for sex discrimination.

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Conflict of interest

None.

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